NONTRAUMATIC BLINDNESS
James F. Finegan

ACRYLIC EYE PROSTHESES
Warren V. Hanson

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II. NONTRAUMATIC BLINDNESS

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Of the 157 cases thus far received on the service for rehabilitation of the blind, 58 were due not to trauma but to various pathologic factors. All these patients had spent considerable time at other Naval hospitals and activities prior to their admission here; therefore we did not see them in the acute stages of the diseases which produced blindness. An analysis in terms of etiology is presented, and each of the main etiologic groups is discussed in the light of our experience.

Of the total of 58 patients, 41 were sailors and 17 were Marines. All were enlisted men, and the group's average age was 26.5 years. Table 1 presents an analysis of the group in terms of causal factors.

Methyl alcohol

The causative factor in the greatest number of cases was the ingestion of methyl alcohol. These numbered 28; therefore nearly 50 percent of the nontraumatic cases of blindness were due to an avoidable cause. All these patients came from the Pacific theater of war.

Aside from the high incidence, there was nothing unusual about them. These men, with one exception, gave a history of drinking some unorthodox mixture known later to contain methyl alcohol. The substance consumed was variously stated as having been "ditto" fluid, torpedo juice, carburetor alcohol, anti-freeze, et cetera. The exception was the individual who insisted that he drank "good" liquor in profuse quantities for several weeks at which time he suddenly noticed visual failure while driving a truck. He was in a state of acute alcoholism when he reported for treatment. Since the liquor had been obtained on a small island in the Pacific, and from various sources, its alcoholic content was questionable.

The average age of these patients was 26.1 years, the youngest being 19 years of age and the oldest 37; 17 were sailors and 11 were Marines. The ratio of Marines to sailors in this group (1:1.5) as compared with the ratio of these services as a whole (1:6) shows a significantly higher incidence among Marines.

All gave a typical history of sudden onset of visual loss within 48 hours after ingestion of the poison. All had violent gastro-intestinal

TABLE 1.—*Causes of blindness in 58 cases*

Causes	Total number of cases	Sailors	Marines
Methyl alcohol	28	17	11
Retrobulbar neuritis (cause undetermined)	8	6	2
Macular choroiditis, bilateral	7	7	0
Severe vitamin deficiency	6	3	3
Uveitis	2	2	0
Brain tumor	1	1	0
Cavernous sinus thrombosis	1	1	0
Diabetes mellitus	1	1	0
Secondary optic atrophy	1	1	0
Multiple sclerosis	1	1	0
Retinitis pigmentosa	1	1	0
Exposure keratitis	1	0	1
Totals	58	41	17

disturbances also at the onset. Their records show that all had an optic neuritis visible with the ophthalmoscope at the time the visual loss occurred. As the neuritis subsided, the vision improved for a few days in most cases but gradually failed again.

By the time the patients were admitted to this service, usually several weeks after onset, all had marked optic atrophy. Examination revealed pallor of the disks with the lamina cribrosa plainly visible. Visual fields were typical. All showed bilateral scotomata extending out from fixation to as much as 10 degrees. There was only slight contraction of the peripheral fields in the patients retaining more than light perception. Four patients had no light perception in either eye; seven had light perception only in each eye. The best vision obtainable in this entire group showed right eye 4/20; left eye light perception. In this latter case the peripheral field was markedly contracted in the better eye.

All of these patients had been given massive doses of thiamine chloride intravenously during the acute stage of poisoning, and at this activity continued to receive multiple vitamins supplemented by thiamine chloride. None showed any improvement in vision after admission here.

Retrobulbar neuritis and multiple sclerosis.—There were nine cases of retrobulbar neuritis producing blindness. The youngest patient in this group was 20 years of age and the oldest was 49 years, the average age being 28.9 years. Six of the men were sailors and two were Marines. All showed bilateral central scotomata when the fields were charted. These men were thoroughly studied for foci of infection, either at other activities prior to admission here, or if the studies were not complete, they were completed here. One patient was found to have badly infected tonsils and a tonsillectomy had been performed prior to admission. Another man had received treatment for an infected antrum. Six cases showed no foci of infection. All of these men had neurologic examinations to determine the possible presence of multiple sclerosis. Only one man, a 21-year-old sailor, showed definite evidence of the latter disease, having right hemihypesthesia, diminished corneal reflexes, and absent pharyngeal reflexes in addition to temporal pallor of the disks and central scotomata. It will be interesting to follow the subsequent neurologic developments in these men.

Macular choroiditis.—There were seven patients in the series in whom the visual deficiency was caused by bilateral macular choroiditis. The youngest in the group was 20 years of age and the oldest 52, the average age being 27.9 years. All of these men were sailors. On admission one patient had 9/200 and 15/200 vision in the right and left eyes respectively. On discharge his vision had improved to 6/20 and 10/20, which was the best vision in the entire group. One patient had 4/20 vision in each eye, another had 3/20 vision in each eye. The remainder had less than 7/200 in either eye. One man had light perception only. These patients had all been studied for foci of infection prior to arriving here. All had been treated by the administration of typhoid vaccine intravenously for several doses. With the exception of the one case mentioned, the macular lesions appeared healed when first seen here and showed no signs of activity subsequent to admission.

Severe vitamin deficiency.—The most interesting group in this series of cases consisted of six men who had blindness associated with malnutrition and severe vitamin deficiency. The average age of this group was 28.7 years, the youngest being 23 and the oldest 36 years. Three of the men were sailors and three were Marines. These men had been imprisoned by the Japanese following the fall of the Philippines in 1942. Their daily diet while in prison consisted of about 250 gm. of rice and a cup of thin soup made from potato vine and radish tops. About once every 2 months a square-inch piece of fish was added to this diet. After 6 months on this diet, they began to experience visual failure which became progressively worse. At the same time they had been suffering from beriberi and pellagra.

Central vision was most affected, the peripheral field of vision remaining intact. One man stated that 3 months after the onset of blindness he was given several injections of vitamins intramuscularly by the Japanese. Following these injections, his vision showed no further impairment but there was no discernible improvement. One man developed a corneal ulcer in the right eye while in prison. This went untreated. When admitted here his right eye showed a large corneal leukoma to which the iris was adherent. An optical iridectomy was done, but the vision was unimproved.

Visual field examinations in these cases showed bilateral central scotomata extending about 5 degrees out from fixation. The peripheral fields were normal. These men have been given massive doses of multiple vitamins and thiamine chloride but their vision has not improved. In two of these cases the optic disks appeared normal. The others showed temporal pallor of the disks in both eyes. None of these patients had ocular muscle palsies.

Uveitis.—Two cases of uncontrollable uveitis produced blindness in this series. Both men were sailors 23 and 26 years of age. Both had severe plastic iridocyclitis. In spite of intensive treatment with cycloplegics, Kettering hypertherm, typhoid vaccine intravenously, sulfonamide drugs and penicillin, the uveitis progressed. Both men developed bilateral secondary glaucoma. One eye was enucleated. Vision was reduced to light perception with poor projection when these men were discharged from this hospital.

Brain tumor.—Brain tumor was the causative factor in one case of blindness. When admitted here, this man's vision was nil. Examination of the fundi revealed bilateral optic atrophy of secondary type. This patient, a 21-year-old sailor, was first admitted to the sick list in September 1943. One month later he was operated upon for removal of a cystic glioma of the cerebellar vermis. There have been no evidences of recurrence in the 2 years that have followed.

Cavernous sinus thrombosis.—On 18 December 1944, a 22-year-old sailor was admitted to this hospital who had had bilateral cavernous sinus thrombosis. Three months previously he had had a sty which caused an orbital cellulitis with subsequent involvement of the cavernous sinuses. He was treated with penicillin and appeared to have made a good recovery. Examination on admission here revealed bilateral choked disks. The vision was nil. Twelve days after admission the patient complained of headache and lethargy. He died on 11 January 1945, 12 days after the onset of these symptoms. An autopsy revealed a large abscess of the left frontal lobe.

Diabetes.—Diabetes was presumed to be the ultimate cause of one case of blindness. On admission this man, a 21-year-old sailor, had vision of 7/200 in the right eye and 10/200 in the left eye. Ophthalmoscopic examination showed bilateral central retinitis. This man had moderately severe diabetes. No other cause for the retinitis could be discovered.

Secondary optic atrophy.—One patient, a 23-year-old sailor, was admitted with bilateral secondary optic atrophy. His records revealed that he had a bilateral papillitis at the time he noted the onset of his visual failure. He had been taking atabrine for 5 days and this was promptly discontinued. All studies on this man failed to reveal any other possible cause for his ocular condition. He was given thiamine chloride and multiple vitamins without improvement. The vision at the time of discharge from the service was light perception only in the right eye and 5/20 in the left eye. The left visual field was contracted to 10 degrees from fixation.

Retinitis pigmentosa.—The case of retinitis pigmentosa in this series occurred in a 19-year-old sailor. Six months after entering the service he complained of night blindness. Further questioning revealed that he had noticed poor vision for 10 or 12 years. The vision was 4/20, corrected to 14/20, in each eye. The visual field was contracted to 10 degrees from fixation in each eye. Ophthalmoscopic examination revealed retinal changes typical of retinitis pigmentosa. Only basic rehabilitation was given this man, since blindness was an eventual possibility even though he had useful central vision.

Exposure keratitis.—A 21-year-old Marine was admitted to the hospital with blindness resulting from exposure keratitis. The keratitis, complicated by perforating corneal ulcers, had developed while the man was in a prolonged coma resulting from a severe attack of malaria. At the same time he had a marked, generalized allergic dermatitis. On admission here the vision was nil in the right eye and light perception only in the left. The right globe was phthisical. The left cornea was completely opaque, the iris was adherent to the cornea at the sites of two old perforations, and the anterior chamber was obliterated.

SUMMARY

Of 157 cases of blindness seen at this hospital 58 were due to factors other than trauma. This group included 41 sailors and 17 Marines. Twelve casual factors have been discussed. Of these cases of blindness, 28, almost half the total number, were caused by the ingestion of methyl alcohol.

III. ACRYLIC EYE PROSTHESES

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The use of plastic materials in eye prostheses has been a great improvement over any former method of restoration. First proposed as a temporary measure by Holmes,[1] the method of applying the acrylic resins in the making of permanent cosmetic ocular replacements was developed during 1944 at the Naval Dental School, Bethesda, Md., by Murphey and his associates.[2] In December, 1944, the manufacture of acrylic eyes was begun at the U. S. Naval Hospital, Philadelphia. The present report concerns our experiences in the production of 200 such prostheses for 90 patients.

The development and application of plastic eye prostheses in the Navy had its origin in the urgent need for a more adequate method of eye replacement than that which existed prior to World War II. Returning casualties presented such a variety of problems that orthodox methods of restoration would not suffice. In many cases damages to the contents of the orbital cavity and to the bony structure surrounding it were so extensive that the ordinary glass prosthesis could not be worn. Some patients resorted to wearing patches rather than a prosthesis. To deal with this problem, a program was instituted at the Naval Dental School at Bethesda to develop an ocular prosthesis which would meet all requirements. In November 1944 a group of Naval dental officers was ordered to the Naval Dental School for instruction in ocular prosthesis. During the following 6 weeks, this group studied the anatomy of the eye, physical properties and processing of plastics, color theory, and technic of acrylic eye construction. At the end of this instruction period, each officer was sent to a hospital where his services could be utilized.

This activity was initiated at Philadelphia Naval Hospital in December 1944, under the direction of the writer, and began with a backlog of 18 patients. The first eyes were made entirely by the dental officer with the assistance of the medical illustrator who painted the iris. Later a technician was sent from Bethesda who had been trained in various phases of laboratory technic. The service has been carried on in the dental clinic with no special equipment except that used for coloring.

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[1] HOLMES, A. G.: Use of acrylic resin in construction of temporary artificial eyes. Dental Bull. (Supp. to Army M. Bull.) **12**: 265-266, October 1941.

[2] MURPHEY, P. J.; PITTON, R. D.; SCHLOSSBERG, L.; and HARRIS, L. W.: Development of acrylic eye prosthesis at National Naval Medical Center. J. Am. Dent. A. **32**: 1227-1244, October 1, 1945.

The technic used is essentially the same as that originally taught at Bethesda. It has been found more expedient, however, to measure the iris directly instead of photographing the iris and then measuring it. It has been necessary in some cases, where the existing cavity does not have a retentive form, to alter the shape indicated by the original mold so that the finished prosthesis may resemble the conventional glass eye.

Since each case represents an individual problem, the results obtained hinge largely upon the skill and experience of the operator. Although a great many technical difficulties were experienced in the beginning, these have for the most part been eliminated so that, given a good case, it is possible to construct a prosthesis which defies detection. The cosmetic result is entirely dependent upon the illustrator's skill in painting the iris.

PROCEDURE

The following technic has been used at this hospital with a high degree of success, and is particularly adaptable to most of the cases treated here. The first step in constructing a prosthetic eye is a careful examination of the existing socket. In cases in which the socket is puckered or almost obliterated or in which the palpebrae are overlapping, it may be desirable to insert a plastic form, cut to the required size. As the soft tissues of the socket stretch, over a period of 3 or 4 days, the form may be gradually enlarged by adding wax to the periphery. After the cavity has attained a sufficient size, an impression may be taken with any colloidal impression material.

The impression is taken by placing a soft mix of impression material in a glass cylinder fitted with a plunger and, over the other end, a common rubber nursing nipple in the end of which a 3/16-inch hole has been cut. The nipple is placed between the lids and the material gently forced into the socket. The socket is filled and the material allowed to extend out over the lid so that a perfect negative is obtained of the inside and outside of the eye socket.

The impression obtained is surrounded with plaster of paris, which, after setting, results in a positive mold of the eye socket. This mold is then divided in half and used to construct a wax pattern. The pattern is fitted to the eye socket and adjusted to provide maximum movement and comfort and to restore as nearly as possible the natural contour. The finished wax pattern is then treated by flasking in an ordinary compression flask with a compensating spring compress. After separating, the mold is lined with tinfoil. The visible portion of the sclera is then dry-packed in order to obtain a suitable color.

Sufficient blue-tinted opaque polymer is poured into the outer portion of the mold to extend about 3/16 inch beyond the periphery of the iris. This is wetted down with monomer. The remainder of that half is then filled with yellowish-orange tinted powder and wetted down with monomer. This is backed with opaque material which has been allowed to stand in the mixing jar until it has a rubbery consistency and is quite dry. The flask is closed, with cellophane between the halves, and placed in a press for 3 minutes. The flask is then opened, the excess is trimmed away, and after closing, the flask is placed in the compress. Curing should be done slowly for about 4 hours at 160° Fahrenheit. The finished sclera is removed from the flask and polished.

The completed sclera is placed in the eye socket and checked for movement, comfort, and contour. If the result seems satisfactory, the position of the iris is determined by measuring the position of the center of the remaining eye (in unilateral loss) and marking the corresponding point on the artificial sclera. If both eyes have been lost, a spot of dark wax is placed on each sclera at the approximate location of the center of the pupil. The scleras are then placed in the cavities and the arbitrary points are shifted until the operator is satisfied with the result.

After the iris has been located, a cavity is prepared in the sclera with suitable stones. The cavity should be exactly the size to accommodate the iris and present a slightly convex posterior wall.

The surface of the sclera is roughened with a stone, and the blood vessels are drawn with red ink and a quill pen. The sclera is covered with 24-gage casting wax to which is added a button of wax over the cavity prepared for the iris. The sclera is flasked, separated, and the wax washed away with boiling water. The case is then ready for the transparent covering.

At some time during the process of preparing the sclera, the artist paints an iris exactly reproducing the color and detail found in a natural eye. In cases where there is an existing eye, the illustrator is faced with the task of copying what he sees in the iris of the patient. The problem of painting irises for those with bilateral loss is a little different, since there is no existing iris to reproduce. The patient is asked what color of eyes he had, and then usually a search is made for a model with eyes of the color suggested by the patient. It is very important that the eye color blend with the complexion tones and hair color of the patient, else the over-all result will not be pleasing.

The actual painting is done with water colors on tiny circles of water color paper of a size to correspond with the size of the iris. The usual size of the iris of a human eye is between 11 and 12 mm. in diameter.

First, a small circle is drawn in the center of the prepared paper circle with a compass and filled in with black ink. This is the pupil. Now the illustrator is ready to mix the basic eye color, which is the predominating color seen upon looking at a person's eye. This color is obtained by much juggling with the three primary colors, red, yellow and blue. If the eye is of a decided gray tone, just the right amount of complementary color must be added until the color is an exact match for the iris color. After this basic color is obtained, the painting is done with delicate radiating stroking and all of the feathery detail is reproduced until the illustrator is satisfied with the result.

The finished iris is allowed to dry and is then molded into a convex shape to fit the contour of the prepared sclera, and cemented into the shallow depression which has been cut out for it. Next, the transparent material, which has been prepared by wetting down with monomer and allowing to set until it has reached a rubbery consistency, is placed over the sclera and attached iris. The whole is covered with cellophane and the top part of the flask set in place. The whole flask is placed in a compress for 5 minutes, after which it is opened, any excess is trimmed away, and the flask again closed with fresh cellophane.

The flask is enclosed in a compress and placed in cold water, which is brought slowly to a boil, after which it is allowed to simmer for about 20 minutes. It is allowed to cool slowly and the eye is removed from the flask. There is usually some excess material adhering to the completed eye which must be carefully trimmed away with a stone. The surface of the prosthesis is contoured, care being taken to maintain a scleral sulcus.

The last and one of the most important steps in the construction of the ocular replacement is that of polishing. If the prosthesis is to simulate a natural eye, it must have an extremely smooth, shiny surface. This is obtained by careful work with a rag wheel, pumice, and rouge. At the completion of this operation, the sclera is subjected to a good soap-and-water scrubbing and is then ready for insertion in the eye socket.

If this technic is carefully followed, it will give uniformly good results. Details of color and appearance are limited only by the skill of the operator and the artist, and by conditions beyond their control, such as an unusually mutilated socket or lid. Great personal pride is felt by the patient when he is properly fitted with a prosthesis and need no longer fear to face the world because of his disfigurement.

CASE MATERIAL

Ocular prostheses have been constructed for 90 patients at this hospital. Of this number, 17 had suffered the loss of both eyes. The total number of eyes constructed is now two hundred. The large majority of these patients had lost their eyes through violence in battle and had suffered considerable mutilation of the orbital cavity and the surrounding tissues. These were the cases in which plastic prosthesis has been of the utmost value. Heretofore, it has been impractical if not impossible to attempt to fit badly mutilated eye sockets with the conventional type of glass eye. The plastic eye form constructed from an impression of the remaining cavity offers a means of dealing with this problem. By means of a graduated series of forms, the socket may be dilated to its natural size or at least to a size sufficient for the insertion of an iris. This procedure has been of great aid to the plastic surgeon in restoring lost portions of tissue surrounding the sockets.

Advantages

The chief advantages of these eyes are lightness of weight, durability, tissue tolerance, and permanence of color. There is no danger of the eye bursting in the orbital cavity as glass eyes sometimes do, and the material is unaffected by the fluids of the eye socket. Since the prosthesis is made from a positive plaster mold, which in turn is made from a negative impression of the cavity, the plaster mold serves as an excellent record of the case at the time the eye was made.

Not the least of the benefits derived from plastic eye prosthesis is the spirit of confidence and appreciation engendered in the patient, who feels that particular interest is being taken in his case. Even in cases in which it is impossible to obtain a good cosmetic result, the patient usually shows an improvement in morale. When good results have been obtained and the patient hears expressions of approval from friends and relatives, the improvement in morale is remarkable.

Disadvantages

One disadvantage has been encountered, and that in only one patient; namely, chemical irritation of the tissue lining the socket by the plastic material itself. In one of our most recent patients, a man who had lost one eye, the wearing of the prosthesis was followed in 3 or 4 days by a gradually increasing outpouring of mucus. The irritation stopped soon after the removal of the prosthesis, only to recur with the resumption of its use. It became necessary to substitute a glass eye, and thereafter the patient had no further trouble.

This was probably an instance of idiosyncrasy on the part of the patient to the acrylic resin itself. It raises the question of the possibility of the development of a true sensitization to the material in some persons of allergic constitution. The possibility cannot be denied, but one would expect this to happen as a rule within a month or so of the first wearing of the prosthesis. Yet, thus far it has not occurred in any of our other patients.

A caution must also be mentioned with regard to the care of the prosthesis. It was noticed one day that the iris color of the prosthesis of one of our patients had faded considerably. It then developed that while he had been subjected to some operative measure in the eye clinic, a nurse had put his prosthesis into a basin containing alcohol to safeguard it against contamination. The resin and the cement being soluble in alcohol, fissures into the interior resulted, so that the water colors were leached out of the iris. An acrylic prosthesis should never be exposed to organic solvents.

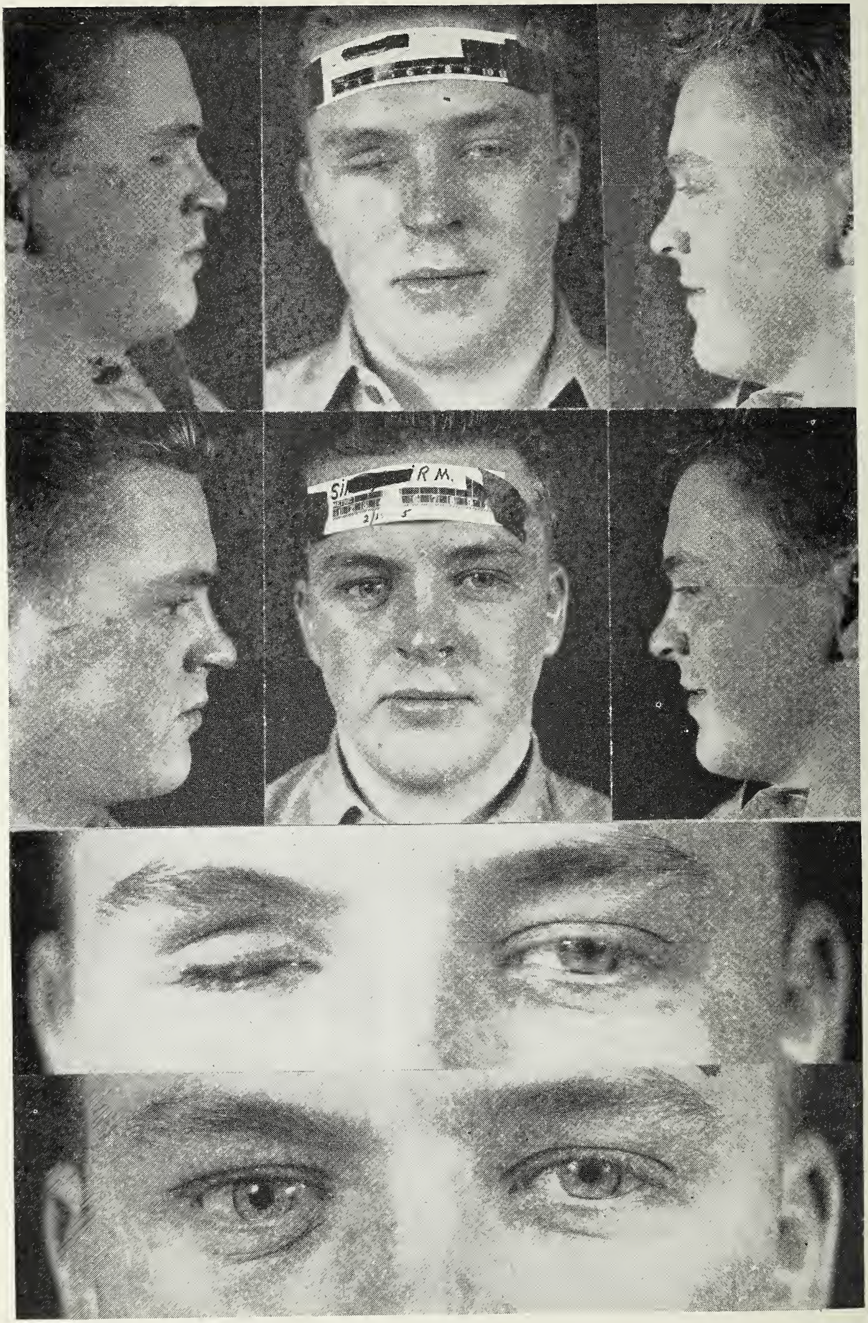
CASE REPORTS

Case 1. (Unilateral replacement).—A 22-year-old Marine, as a result of a land mine explosion, suffered a total destruction of the right eye, which had to be enucleated. The left eye was the seat of a traumatic choroiditis that reduced the final vision to 4/200. A glass prosthesis for the right socket was supplied. However, it proved to be uncomfortable because of the irregular contour of the socket. The patient found the glass eye particularly uncomfortable in cold weather. The acrylic eye has proved a much more satisfactory restoration (fig. 1).

Case 2.—A 23-year-old Marine suffered extensive injuries from the explosion of an enemy antitank shell. In addition to loss of the left leg at midthigh level and of the left fourth finger, he had two fractures and several soft-tissue wounds from shell fragments. One fragment entered on the right side of the head through a small wound of entrance and traversed the head without much damage until it reached the left orbit, where it destroyed the globe and produced a ragged wound of exit in the region of the left orbital margin. The scar is evident in the illustration (fig. 2).

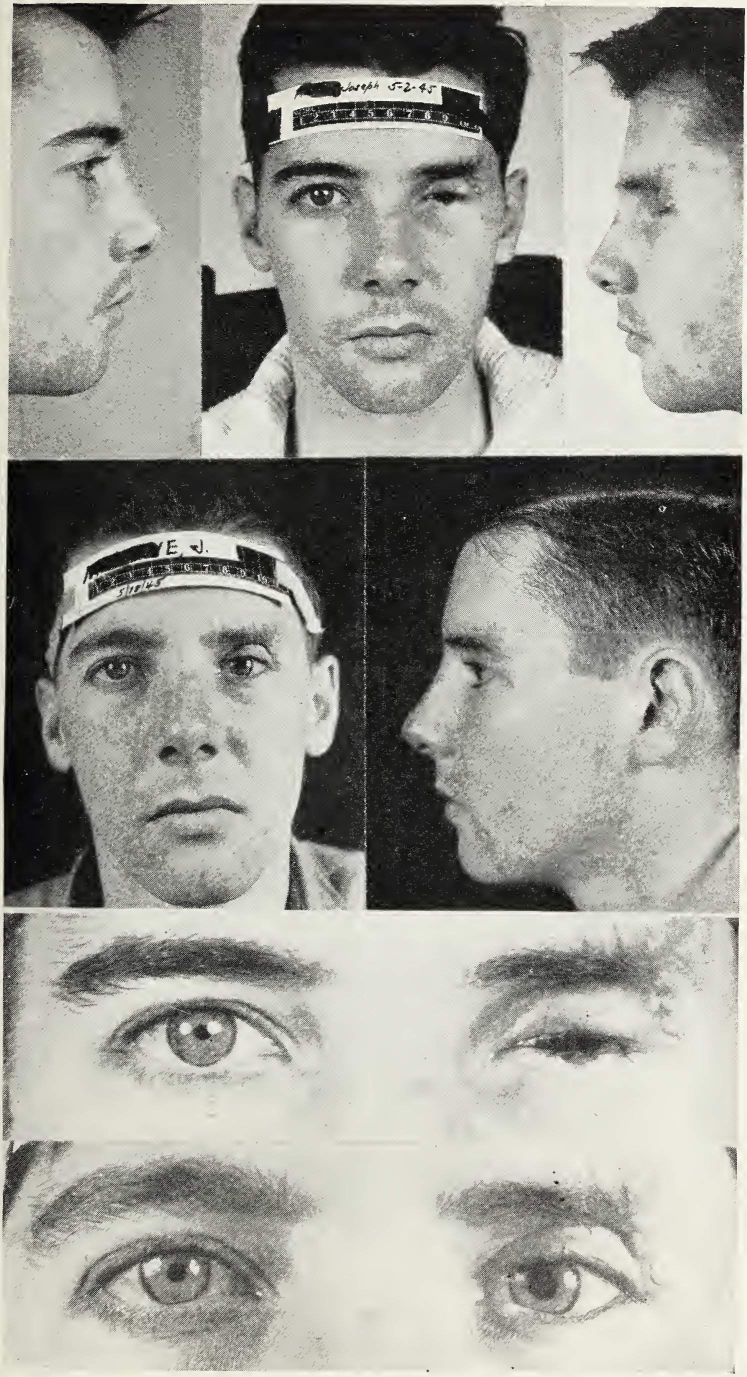
Case 3. (Bilateral replacement).—A 20-year-old Marine was injured on Okinawa in an ammunition explosion. Because of multiple wounds from small fragments, the right eye had to be eviscerated and the left eye enucleated. The excellence of the double restoration (fig. 3) has been commented upon by many of his associates, with a consequent remarkable improvement in the patient's morale.

Case 4.—A 24-year-old Marine was wounded by a hand grenade that destroyed the sight of both eyes. The left eye had been enucleated and there was phthisis bulbi in the right at the time of his admission here. A great improvement in his morale was effected by the bilateral acrylic restoration

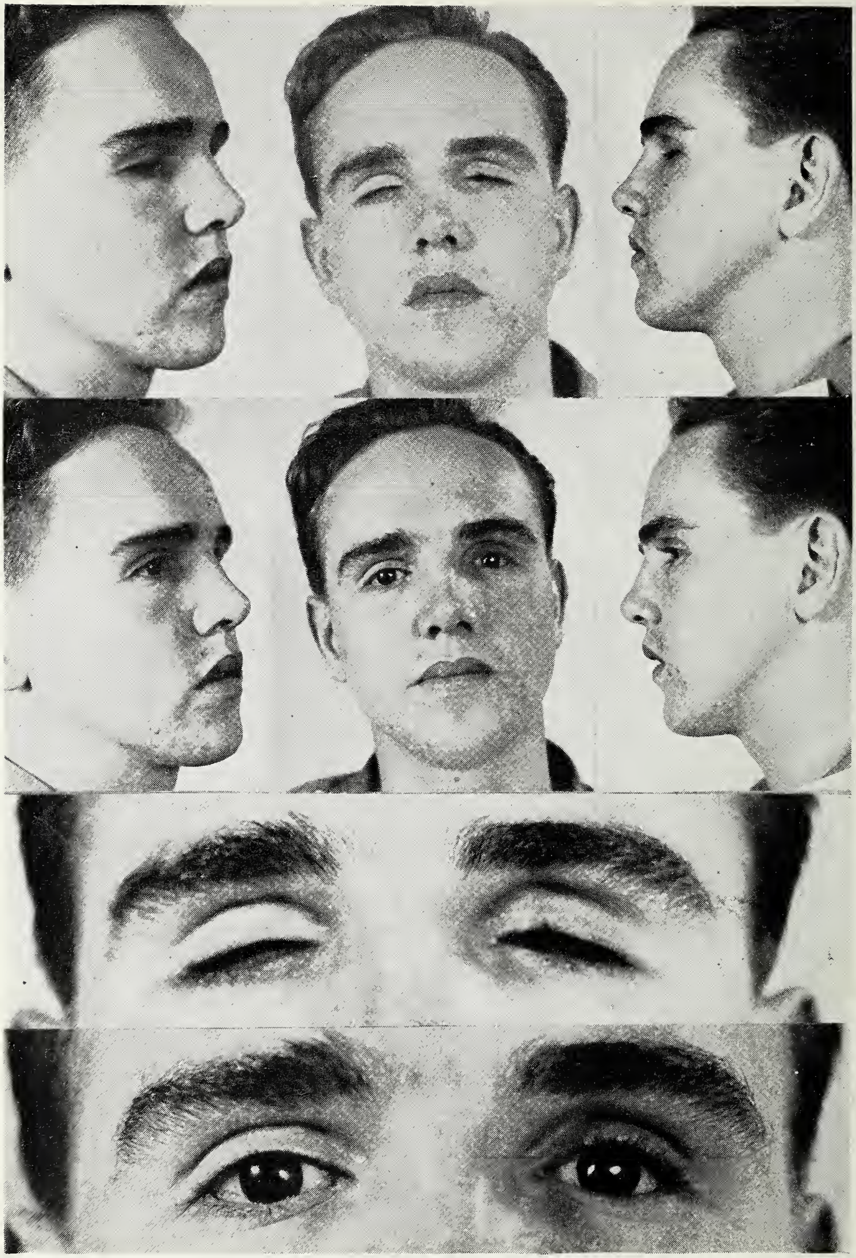


1. Unilateral replacement. (Above) Glass prosthesis, right eye. (Below) Acrylic prosthesis.

shown in figure 4. Attention is called to the motion of the prostheses of which the patient is capable.

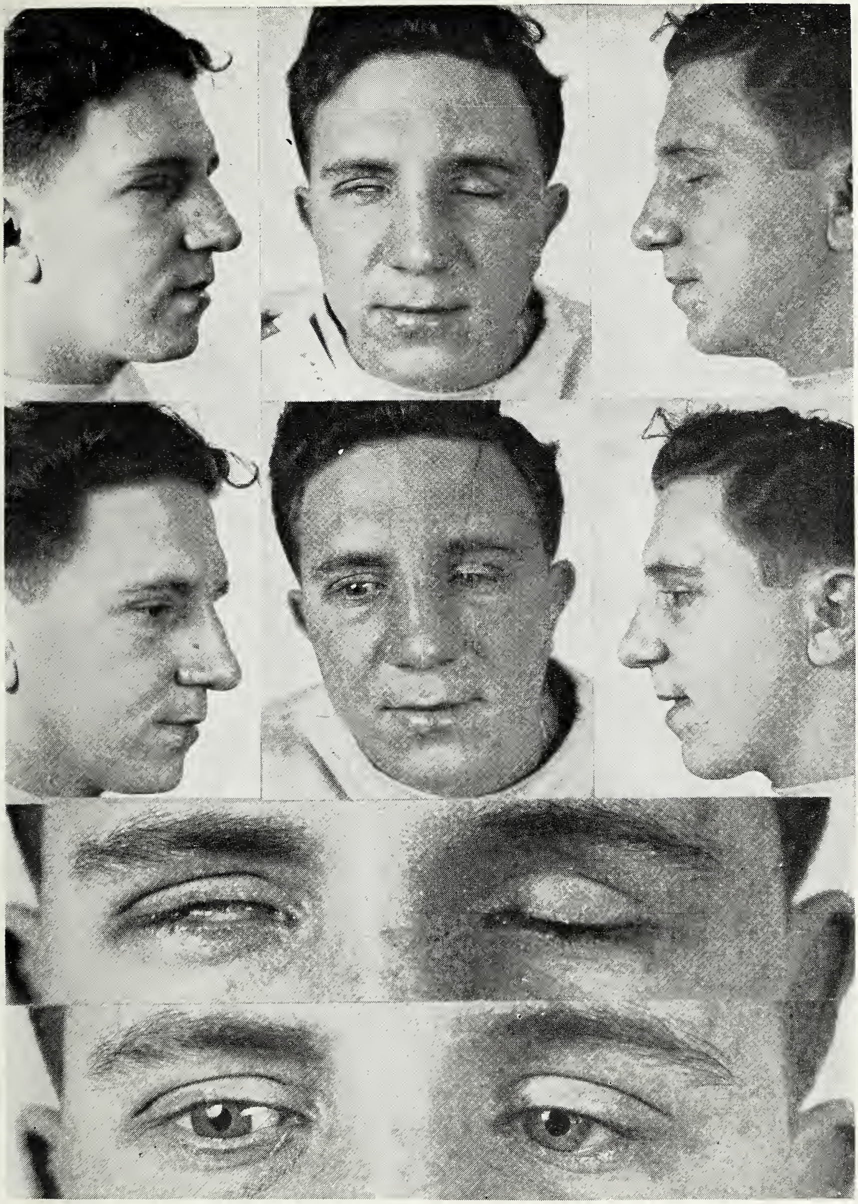


2. Unilateral replacement. Acrylic prosthesis, left eye.



3. Bilateral replacement with acrylic eyes.

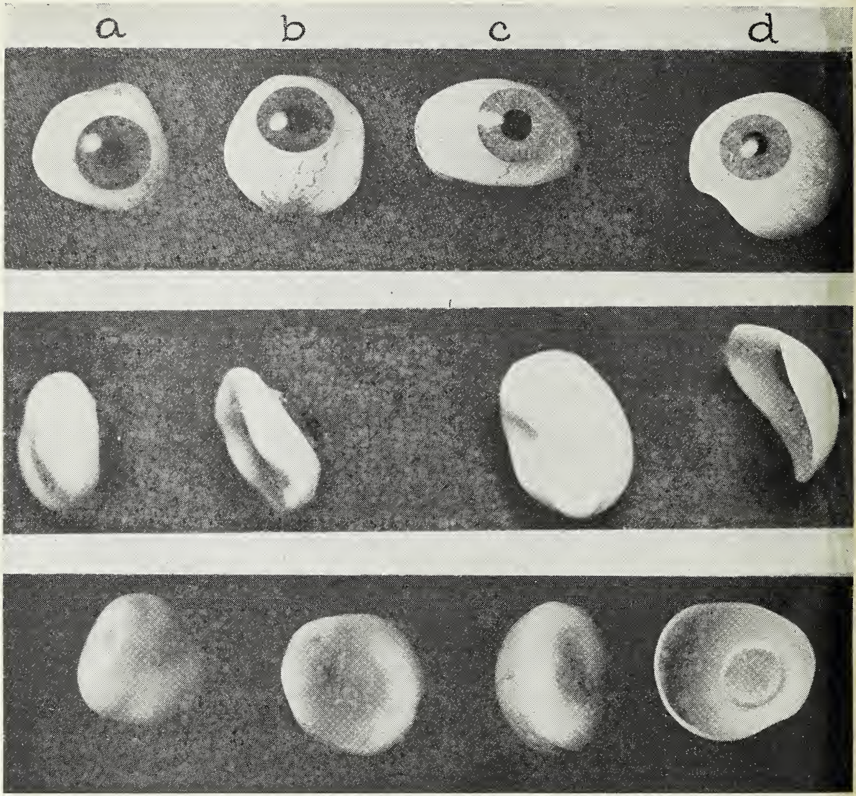
In figure 5 are shown several acrylic resin and glass eyes for comparison. The conformation of the plastic prosthesis to the exact shape of the socket is apparent.



4. Bilateral replacement. Note the motion of the acrylic prostheses of which the patient is capable.

SUMMARY

A report has been presented on the construction and fitting, since December 1944, of a total of 200 acrylic eyes at the U. S. Naval Hospital, Philadelphia, and definitive procedures have been outlined.



5. Acrylic and glass prostheses. Vertical columns a, b, and c are acrylic; column d, glass. Note shape of acrylic prostheses, which conform to contour of socket.

Procedures are essentially similar to those instituted at the Naval Dental School, Bethesda, Md., with the exceptions that photography prior to measurement of the iris has been dispensed with, and that in cavities without retentive form, the shape of the mold is altered.

It is believed that the use of plastic materials in eye prosthesis presents several advantages. In terms of restoration, the plastic prosthesis offers lightness of weight, durability, tissue tolerance, and permanence of color. In terms of psychology and esthetics, a successful prosthesis restores confidence and assurance to the patient; even in cases which do not lend themselves to ideal cosmetic results, the reflection in patient morale has been salutary.

The only disadvantage of the acrylic prosthesis seems to be in the rare instance in which the material proves irritating to the tissues of the socket. One such patient has been encountered.

Acrylic eyes must not be exposed to organic solvents, such as alcohol, in which they are soluble.

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NONTRAUMATIC BLINDNESS
ACRYLIS EYE PROSTHESES
Warren V. Hanson

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